POLARIZATION EXPERIMENTS WITH ANTIPROTON BEAM

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CONTENT

- Existing polarization results with antiprotons
- Perspectives for polarized antiproton physics
  - SPASCHARM asymmetry (polarization) measurements
  - PANDA polarization studies, including CP-violation
  - PAX (PANDA) perspectives

WHY POLARIZATION STUDY IS INTERESTING?

- Large Hyperon polarization, large single-spin asymmetries in inclusive and exclusive reactions (exclusive – Protvino 198.., Inclusive: Protvino 1988, BNL 1988, E704 199.., FODS 200.., RHIC). Asymmetry is large and almost the same for pions at all energies.
- Current theory does not describe whole sample of results, standard model predicts few of %s, different models mainly predict decrease with p_T increase
- Nucleon spin structure much more complicated than we thought before SMC (EMC, HERMES…). Too many aspects to be studied.

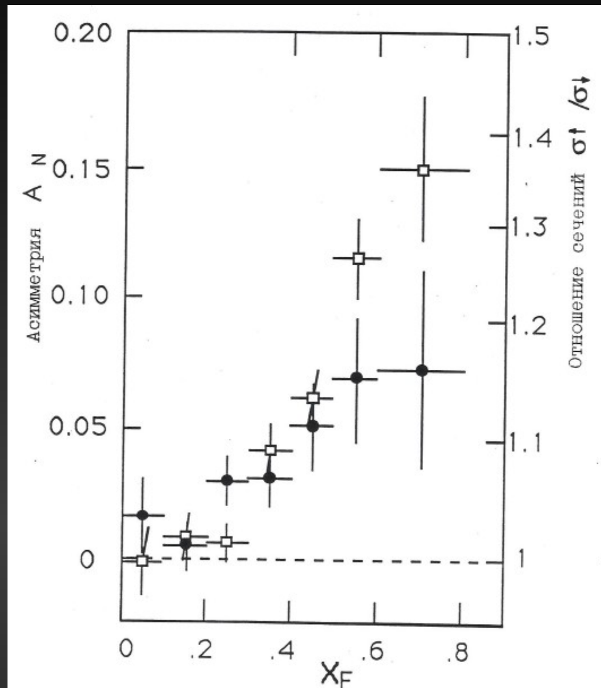
WHY ANTI-P P IS INTERESTING?

1. Simply there are no (almost) data.
2. Direct access to annihilation channel (pp reactions give mainly access to qg processes and gg-processes):
   - Access to glueballs, exotics, heavy quarks… (see Marco Talk for example)
   - Access to the nucleon spin structure (DY, form-factor measurements, transversity…) – many talks here
   - Possibility to search for CP violation in polarization experiments.

EXPERIMENTS AT LOW ENERGIES (PS185)

- Measurement of spin observables in exclusive anti-p p --> Antilambda Lambda production. AIP Conf.Proc. 549 (2000) 697-700
- Measurement of spin transfer observables in anti-proton proton ---> anti-Lambda Lambda at 1.637-Gev/c, Phys.Rev.Lett. 89 (2002) 212302
- Experimental determination of the complete spin structure for anti-p p ---> anti-Lambda Lambda at p(anti-p) = 1.637-GeV/c Phys.Rev. C74 (2006) 015206

E704 DATA



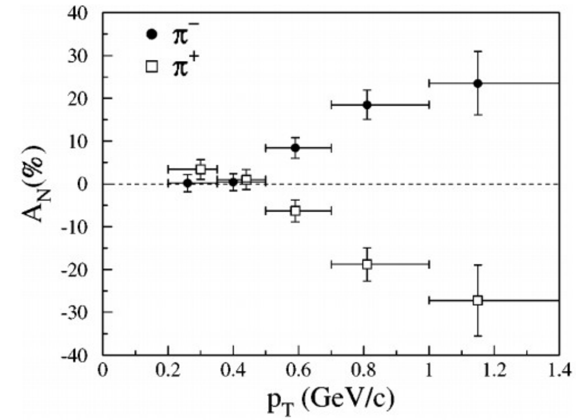


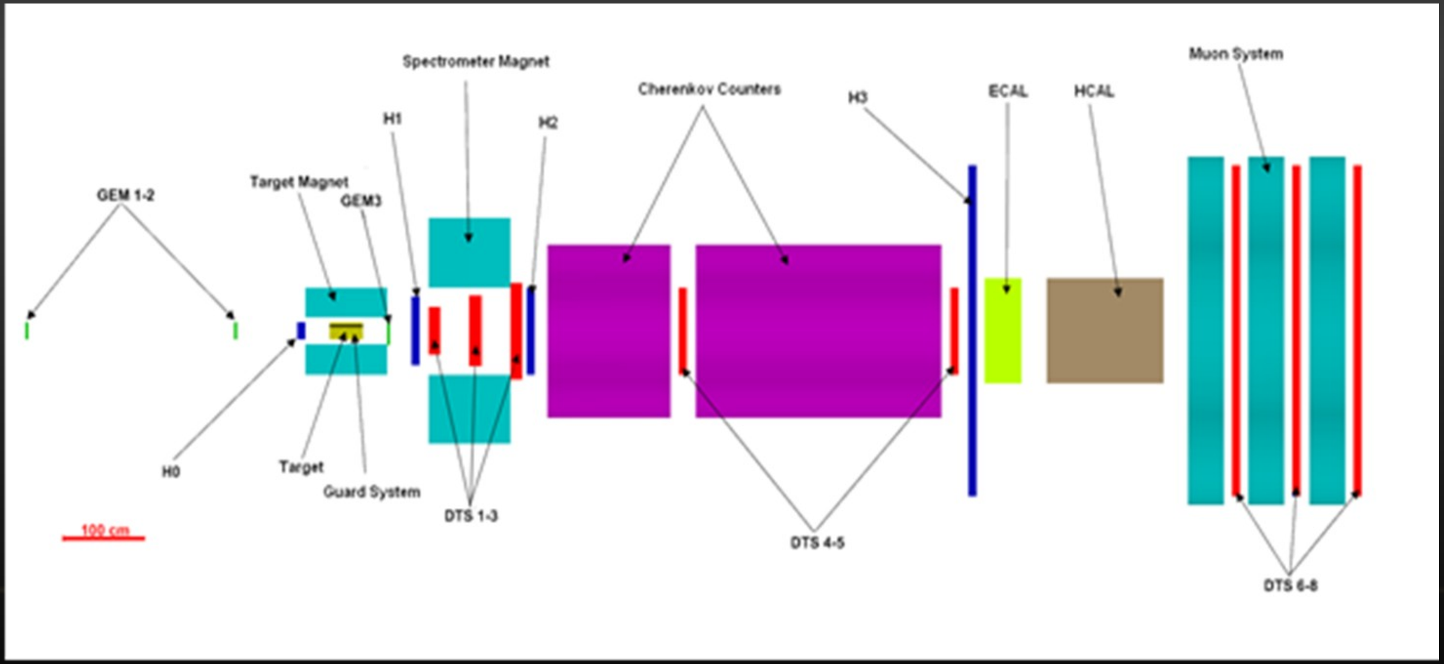
FIG. 2. A_N data as a function of p_T for π^- (full circles) and π^+ (open squares) in the x_F range of 0.2–0.9. For clarity, the first two π^- (π^+) data points are offset by −0.02 (+0.02) GeV/c.

Phys. Rev. Lett. 77, 2626 – Published 23 September 1996

- **High x(t) single spin asymmetry in pi0 and eta production at x(F) = 0 by 200-GeV polarized anti-protons and protons Phys.Lett. B276 (1992) 531-535**
- **First results for the two spin parameter A(LL) in pi0 production by 200-GeV polarized protons and anti-protons Phys.Lett. B261 (1991) 197-200**

SPASCHARM EXPERIMENT (FIRST IN TIME)

- SPASCHARM experiment will start physics program this fall. (SPASCHARM – wide acceptance multipurpose spectrometer).
- First stage: study spin effects with polarized target and unpolarized beam
- Second stage – polarized proton and antiproton beam



SPASCHARM PHYSICS

- **Single–spin asymmeties**: inclusive and exclusive reactions, including elastic, of the light (u, d, s – quarks) hadrons in the beam fragmentation region with polarized beam or target
- The hyperon and vector mesons **polarization** and depolarization
- Study dependence on kinematic values ($0<x_F<1$, $0<p_T<2.5$, $12<E_{Beam}<70$ GeV), event multiplicity and atomic number with high precision due to full azimuthal coverage within the wide aperture
- **Double-spin asymmetry** A_{LL} in charmonium production to study gluon polarization $\Delta G/G(x)$ at large x_F

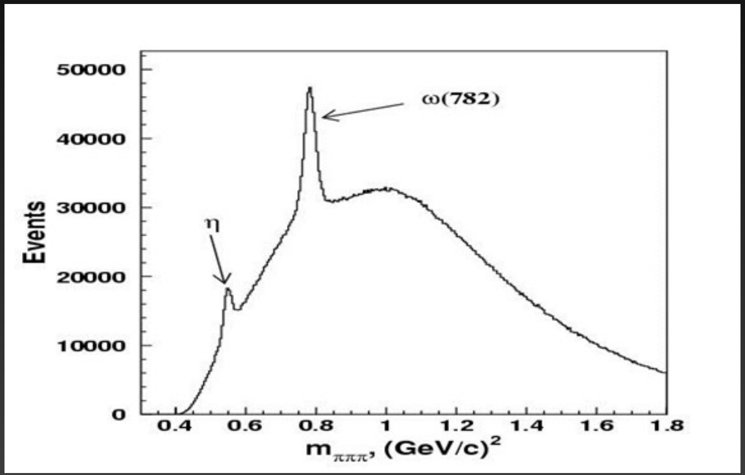
EXPECTATIONS (STATISTICS) Π^- -BEAM

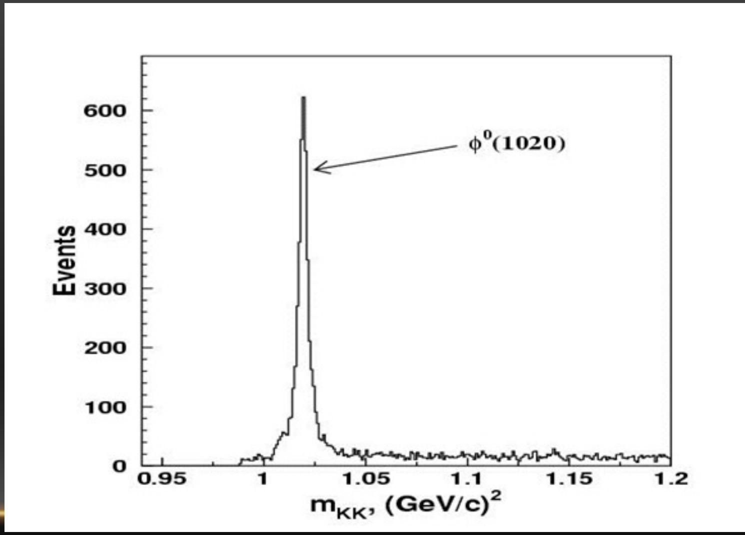
№	particle	N_{EV}	B/S	№	Particle	N_{EV}	B/S
1	• π^+	$4.2\cdot10^9$		20	$\eta \to \pi^+ \pi^- \pi^0$	$5.3\cdot10^6$	0.2
2	π^-	$8.7\cdot10^9$		21	$\omega(782) \to \pi^+ \pi^- \pi^0$	$3.5\cdot10^7$	0.25
3	K^+	$6.7\cdot10^8$		22	$\omega(782) \to \gamma \pi^0$	$3.8\cdot10^7$	2.0
4	K^-	$9.0\cdot10^8$		23	$\varphi(1020) \to K^+ K^-$	$4.3\cdot10^6$	0.3
5	p	$9.2\cdot10^7$		24	$\rho^+(770) \to \pi^+ \pi^0$	$2.9\cdot10^8$	6.0
6	p·	$2.6\cdot10^8$		25	$\rho^-(770) \to \pi^- \pi^0$	$7.5\cdot10^8$	3.0
7	n	$3.2\cdot10^8$		26	$K^0_S \to \pi^0 \pi^0$	$1.7\cdot10^7$	3.5
8	n·	$8.0\cdot10^7$		27	$a_0(980) \to \eta \pi^0$	$1.8\cdot10^7$	9.0
9	K^0_L	$1.0\cdot10^8$		28	$\Lambda \to p \pi^-$	$1.4\cdot10^6$	0.1
10	$\pi^0 \to \gamma\gamma$	$4.3\cdot10^9$	0.1	29	$\tilde{\Lambda} \to \tilde{p} \pi^+$	$1.1\cdot10^6$	0.05
11	$\eta \to \gamma\gamma$	$4.2\cdot10^8$	0.5	30	$\Lambda \to n \pi^0$	$1.8\cdot10^6$	3.0
12	$\eta' \to \pi^+ \pi^- \eta$	$8.3\cdot10^5$	0.05	31	$\tilde{\Lambda} \to \tilde{n} \pi^0$	$7.7\cdot10^5$	0.45
13	$K^0_S \to \pi^+ \pi^-$	$1.3\cdot10^7$	0.3	32	$\tilde{\Delta}^{++} \to p \pi^+$	$9.3\cdot10^6$	2.0
14	$\rho^0(770) \to \pi^+ \pi^-$	$4.2\cdot10^8$	2.5	33	$\Delta^{--} \to p\cdot \pi^-$	$2.5\cdot10^7$	5.5
15	$K^{0*}(892) \to K^+ \pi^-$	$1.1\cdot10^8$	0.7	34	$\Xi^- \to \Lambda \pi^-$	$1.9\cdot10^6$	0.1
16	$\tilde{K}^{0*}(892) \to K^- \pi^+$	$4.3\cdot10^7$	2.0	35	$\tilde{\Xi}^+ \to \tilde{\Lambda} \pi^+$	$1.6\cdot10^6$	0.1
17	$K^{+*}(892) \to K^+ \pi^0$	$1.9\cdot10^7$	2.6	36	$\Sigma^0 \to \Lambda \gamma$	$1.2\cdot10^6$	0.5
18	$\tilde{K}^{-*}(892) \to K^- \pi^0$	$3.8\cdot10^7$	1.3	37	$\Sigma^0(1385) \to \Lambda \pi^0$	$3.9\cdot10^6$	0.2
19	$\omega(782) \to e^+ e^-$	$1.7\cdot10^5$	0.5	38	$\rho^0(770) \to \mu^+ \mu^-$	$9.7\cdot10^4$	0.7

EXPECTATIONS (SIMULATIONS) FOR INCLUSIVE REACTIONS

- Asymmetry measurement statistic errors in reactions

  $\pi^- p_\uparrow \to \omega(782)X$, ρX, $\eta'(958)X$ are 0.3÷3% for different kinematic intervals
- Accuracy in the reaction $\pi^- p_\uparrow \to f_2(1270)\ X$ is even better (0.1÷1%)





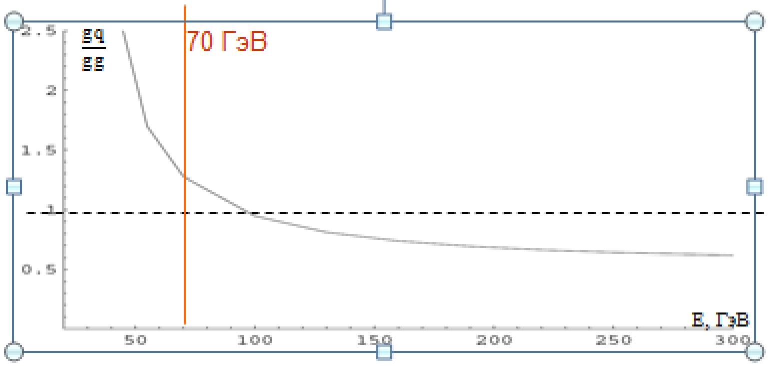
STATISTICS WITH ANTIPROTONS AT PION BEAM

№	частица	N_{EV}	S/B	№	частица	N_{EV}	S/B
1	π^+	$2.1\cdot10^8$		7	n	$1.6\cdot10^7$	
2	π^-	$2.6\cdot10^8$		8	$\tilde{n}$	$1.4\cdot10^8$	
3	K^+	$1.7\cdot10^7$		9	$\tilde{\Lambda} \to \tilde{p}\,\pi^+$	$2.1\cdot10^6$	10
4	K^-	$2.2\cdot10^7$		10	$\tilde{\Lambda} \to \tilde{n}\,\pi^0$	$1.1\cdot10^6$	0.13
5	p	$1.6\cdot10^7$		11	$\tilde{\Delta}^{--} \to \tilde{p}\,\pi^-$	$4.2\cdot10^7$	0.14
6	$\tilde{p}$	$1.8\cdot10^8$		12	$\Xi^- \to \Lambda\,\pi^-$	$1.0\cdot10^5$	10

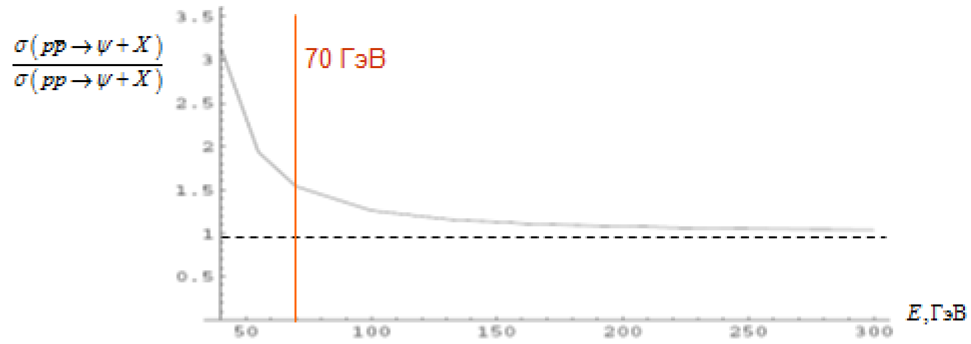
- **New beam-line for polarized antiprotons will be ready 2017 (hopefully).**
- **Polarization will be 40%, luminosity – 10 times higher than for the antiproton in negative (non-polarized) beam, Energy – 16 GeV.**

COMBINATION OF P-P,PI-P AND ANTI-P-P STUDIES

$$\sigma^{pp}(Q) = \sigma^{pp}_{gg}(Q) + 2\left[\sigma^{pp}_{ug}(Q) + \sigma^{pp}_{dg}(Q)\right] + \text{море}$$



$$\sigma^{p\bar{p}}(Q) = \sigma^{p\bar{p}}_{gg}(Q) + 2\left[\sigma^{p\bar{p}}_{ug}(Q) + \sigma^{p\bar{p}}_{dg}(Q)\right] + \sigma^{p\bar{p}}_{u\bar{u}}(Q) + \sigma^{p\bar{p}}_{d\bar{d}}(Q) + \text{море}$$



Charmonium J/ψ and χ_1/χ_2 production:

In pp-reaction q-q(bar) contribution is less than 10%,

In pp(bar)-PANDA and SPASCHARM – qq-bar annihilation gives 95% contribution

Similar behavior for ϕ(1020) meson(?)

SPASCHARM 2-ND STAGE

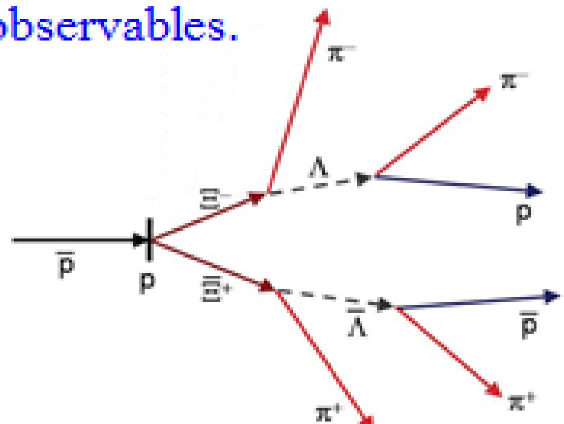
- Stage 2 with polarized and un-polarized beams and without polarized target:
  - Single-spin asymmetry A_N in J/ψ and χ_1/χ_2 inclusive production polarized proton beam. Expected statistics (conservative) for 40 days of data taking is:.
    - p (40 GeV) beam ($5 \cdot 10^7$ p/cycle): 20000 J/ψ and 2500 χ_1/χ_2 states.
  - Statistic error of J/Ψ asymmetry measurements is 7% for
  - The cross-section ratio for χ_1/χ_2 production will be measured to determine the mechanism of charmonium production using pion and proton beams.
- Stage 2 with longitudinally polarized beam and target:
  - Double-spin asymmetry A_{LL} measurements to study $\Delta G/G(x)$.
  - A_{NN} measurements for Drell-Yan pairs(??) to study transverslity ***h(x).*** Simultaneously A_{NN} and A_N in J/ψ, χ_1/χ_2. production will be studied.
  - Double spin asymmetry measurements at different channels

PANDA QCD DYNAMICS

QCD dynamics

The experimental data set available is far from being complete. All strange hyperons and single charmed hyperons are energetically accessible in $p\bar{p}$ collisions at PANDA.

In PANDA $p\bar{p} \rightarrow \Lambda\Lambda, \Lambda\Xi, \Lambda\Xi, \Xi\Xi, \Sigma\Sigma, \Omega\Omega, \Lambda_c\Lambda_c, \Sigma_c\Sigma_c, \Omega_c\Omega_c$ can be produced allowing the study of the dependences on spin observables.



Channel 1.64 GeV/c	Rec. eff.	σ [μb]	Signal
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.11	64	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$1.2 \cdot 10^{-5}$	~ 10	$4.2 \cdot 10^{-5}$
Channel 4 GeV/c			
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.23	~ 50	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$< 3 \cdot 10^{-6}$	$3.5 \cdot 10^{3}$	$< 2.2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$	$5.1 \cdot 10^{-4}$	~ 50	$2.2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma(1385)$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
$\bar{p}p \rightarrow \bar{\Sigma}^0\Sigma^0$	$< 3 \cdot 10^{-6}$	~ 50	$< 1.3 \cdot 10^{-5}$
Channel 15 GeV/c			
$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$	0.14	~ 10	1
$\bar{p}p \rightarrow \bar{p}p\pi^+\pi^-$	$< 1 \cdot 10^{-6}$	$1 \cdot 10^{3}$	$< 2 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$	$2.3 \cdot 10^{-3}$	~ 10	$1.6 \cdot 10^{-2}$
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma(1385)$	$3.3 \cdot 10^{-5}$	60	$1.4 \cdot 10^{-3}$
$\bar{p}p \rightarrow \bar{\Sigma}^0\Sigma^0$	$3.0 \cdot 10^{-4}$	~ 10	$2.1 \cdot 10^{-3}$
DPM	$< 1 \cdot 10^{-6}$	$5 \cdot 10^{4}$	$< .09$
Channel 4 GeV/c	Rec. eff.	σ (μb)	Signal
$\bar{p}p \rightarrow \bar{\Xi}^+\Xi^-$	0.19	~ 2	1
$\bar{p}p \rightarrow \bar{\Sigma}^+(1385)\Sigma^-(1385)$	$< 1 \cdot 10^{-6}$	~ 60	$< 2 \cdot 10^{-4}$

By comparing several reactions involving different quark flavours the OZI rule and its possible violation, can be tested

15-20 Sep 2014 ISHEPP2014 30

Marco Magiora PANDA Talk

EXCLUSIVE DOUBLE HYPERON STUDY

- **Measurement of spin observables – spin density matrix (polarization) and correlation parameters**
- **CP violation**
  - **In decay width Γ(Y → B*π*) and conjugate decay Γ(¯Y → ¯B*π*)**
- **Much more with polarization:**
  - **the asymmetry parameter *α* quantifies the tendency of the decay baryon to be preferably emitted in the hyperon spin direction**
  - **With hyperon decay to another decay additional CP asymmetries can be achieved**

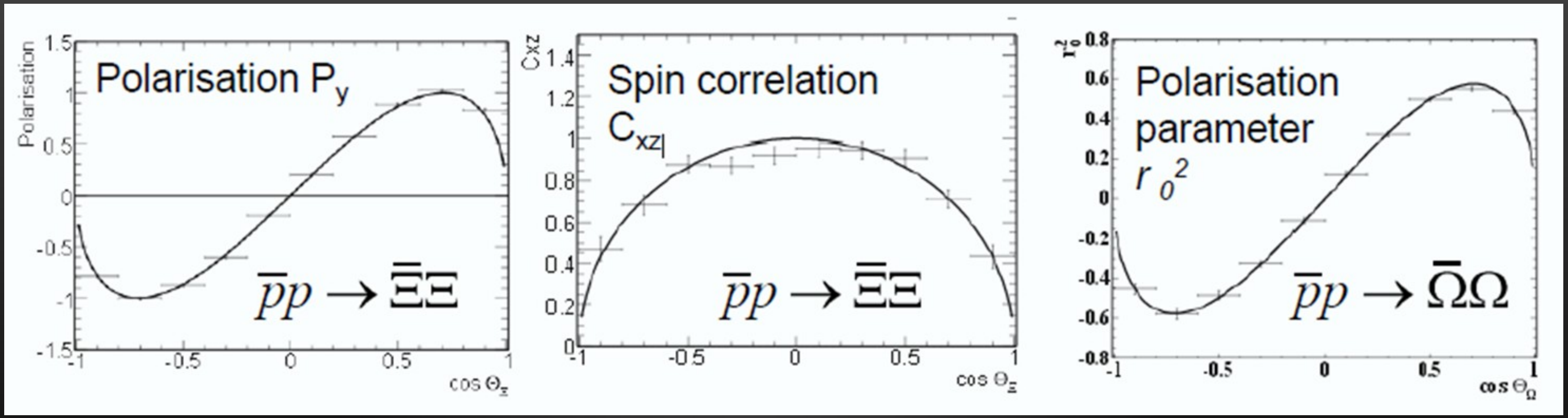
$$A = \frac{\Gamma\alpha + \bar{\Gamma}\bar{\alpha}}{\Gamma\alpha - \bar{\Gamma}\bar{\alpha}} \simeq \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}}$$

$$B = \frac{\Gamma\beta + \bar{\Gamma}\bar{\beta}}{\Gamma\beta - \bar{\Gamma}\bar{\beta}} \simeq \frac{\beta + \bar{\beta}}{\beta - \bar{\beta}}$$

$$B' = \frac{\Gamma\beta + \bar{\Gamma}\bar{\beta}}{\Gamma\alpha - \bar{\Gamma}\bar{\alpha}} \simeq \frac{\beta + \bar{\beta}}{\alpha - \bar{\alpha}}$$

Simulations studies of polarization and spin correlations for Ξ and the recently derived polarization parameters of the Ω show excellent prospects for PANDA

Results and Plots by Erik Thomé, Ph. D. Thesis, Uppsala University (2012).



EXPECTED STATISTICS FOR YY-BAR PAIRS

Momentum (GeV/c)	Reaction	σ (μb)	Efficiency (%)	Rate at $2*10^{32}$ cm^{-2} s^{-1}
1.64	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	64	11	580 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	~50	23	980 s^{-1}
15	$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	~10	14	120 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^{o}$	~40	31	600 s^{-1}
4	$\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$	~2	19	30 s^{-1}
12	$\bar{p}p \rightarrow \bar{\Omega}^{+}\Omega^{-}$	~0.002	~30	~80 h^{-1}
12	$\bar{p}p \rightarrow \bar{\Lambda}_c^{-}\Lambda_c^{+}$	~0.1	~35	~25 day^{-1}

Table prepared by Karin Schönning (BEACH 2014, Birmingham), based on

***Sophie Grape, Ph. D. Thesis, Uppsala University 2009**

**** Erik Thomé, Ph. D. Thesis, Uppsala University 2012**

PAX – PERSPECTIVES (FILTEX)

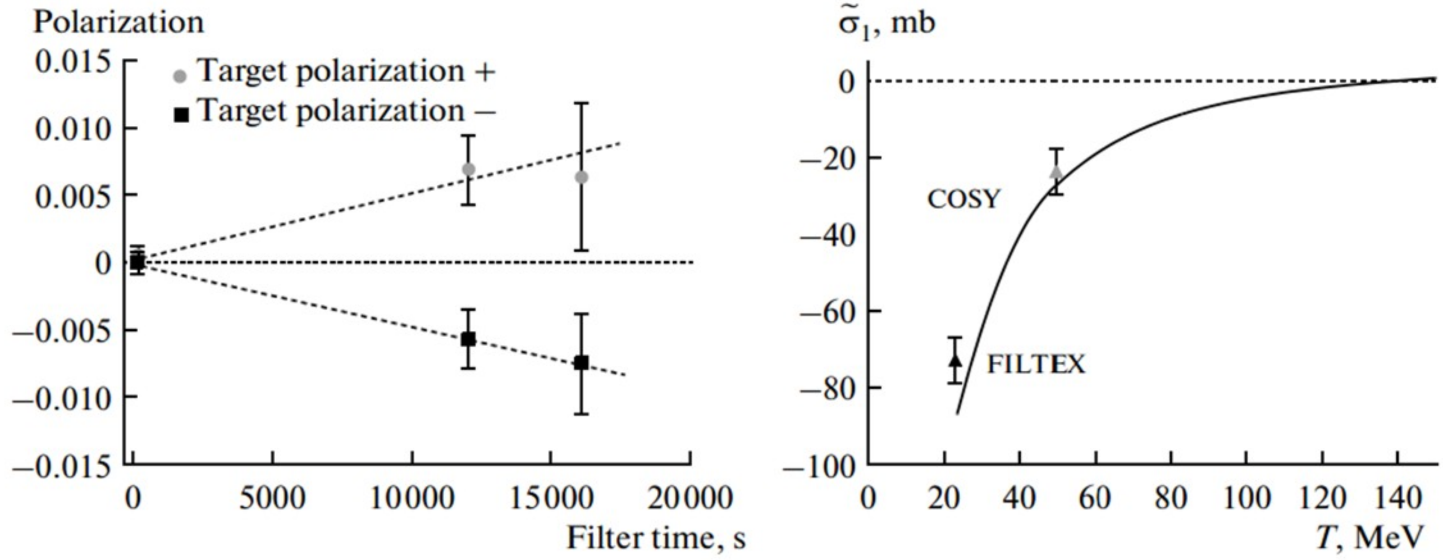


Fig. 2. Achieved polarization after Spin Filtering (left) and effective cross section together with the theoretical prediction (right).

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The Dream – combination of PANDA antiproton beam Intensity and SPASCHARM value of polarization

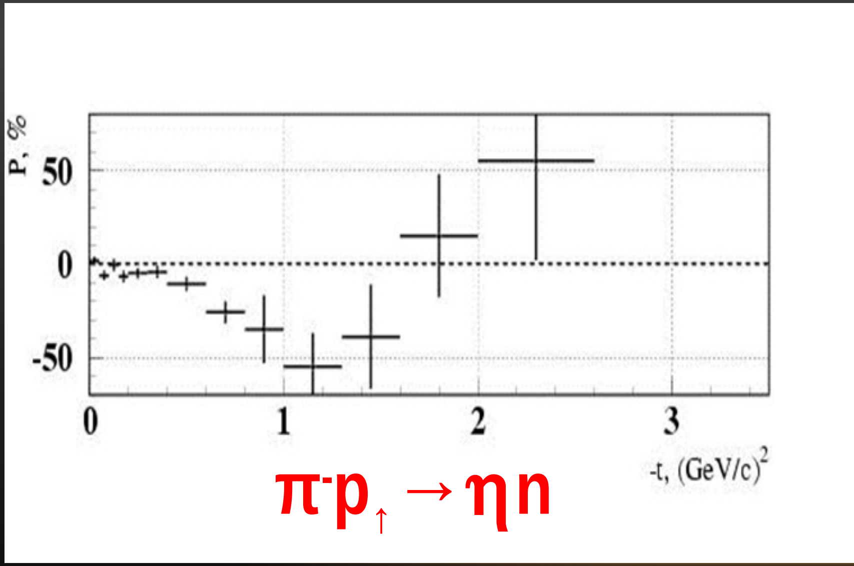
CONCLUSION

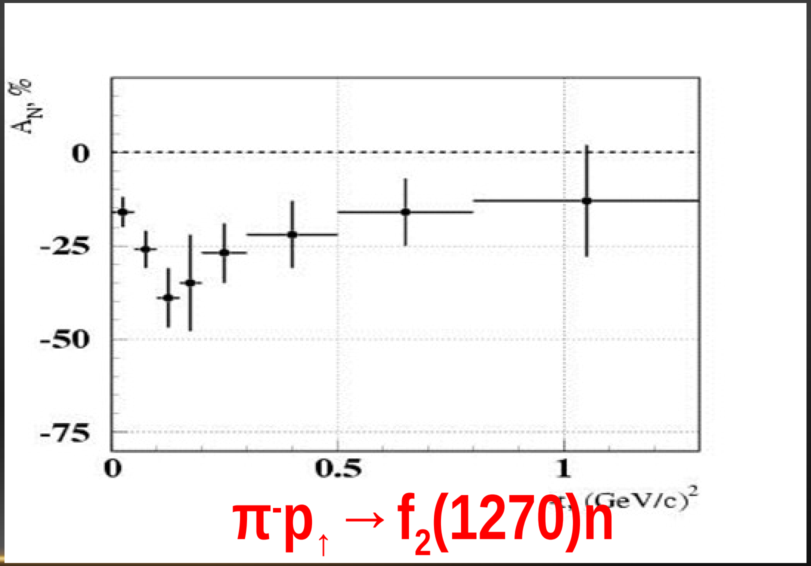
- Antiproton will help us significantly to understand the role (and origin) of spin in hadrons.
- After a long break we will have the possibility to study spin effects with the use anti-proton beam.
- Two experiments (SPASCHARM and PANDA) will complement each other:
  - First data with unpolarized antiproton beam are expected next year
  - First data with polarized antiproton beam are expected in 2017
  - First data with intense antiproton beam are expected in 2019.

BACKUP SLIDES

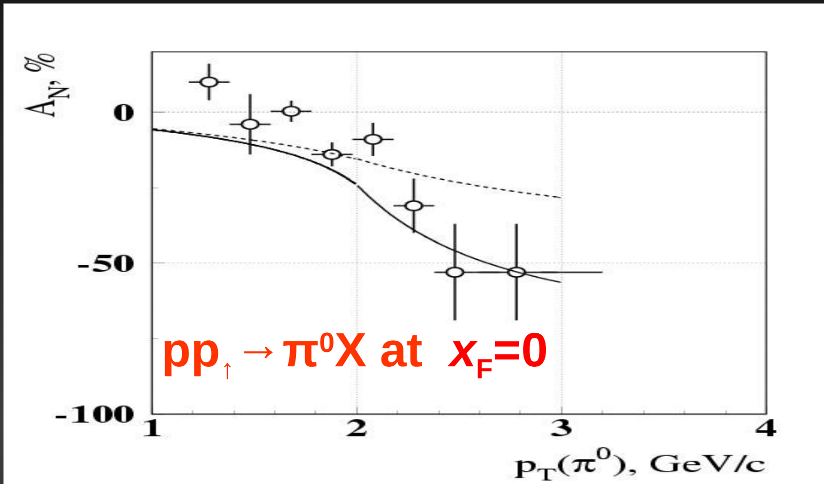
PROTVINO MEASUREMENTS

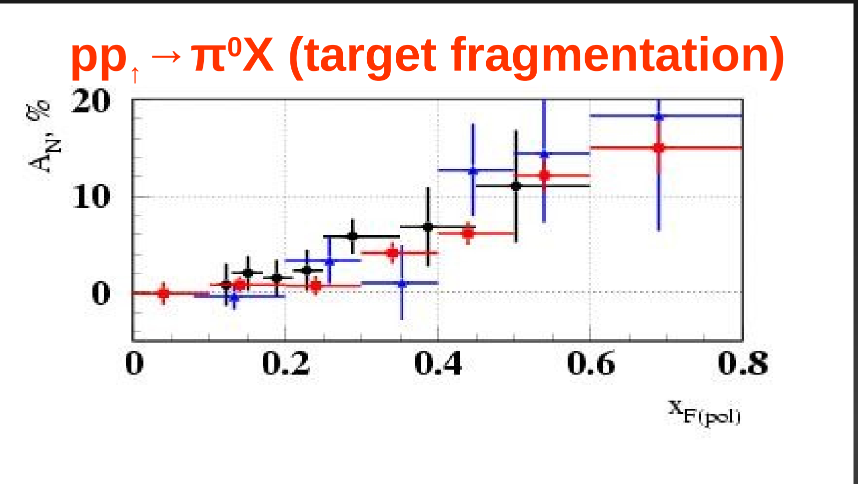
- 1968: Polarization in the elastic scattering of particles and antiparticles
- 1978: Polarization effects in exclusive charge exchange reactions with the Dubna target: large polarization value and its oscillation in exclusive neutral meson (π^0, η, $\eta'(958)$, $\omega(783)$, $f_2(1270)$) production

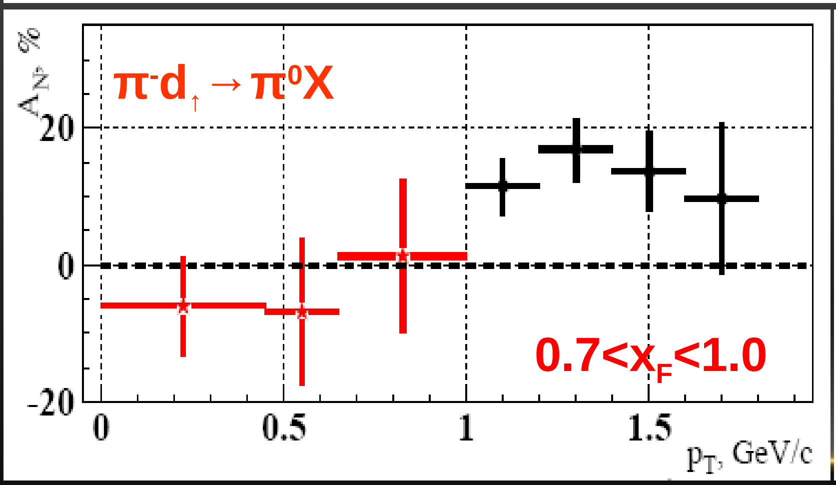


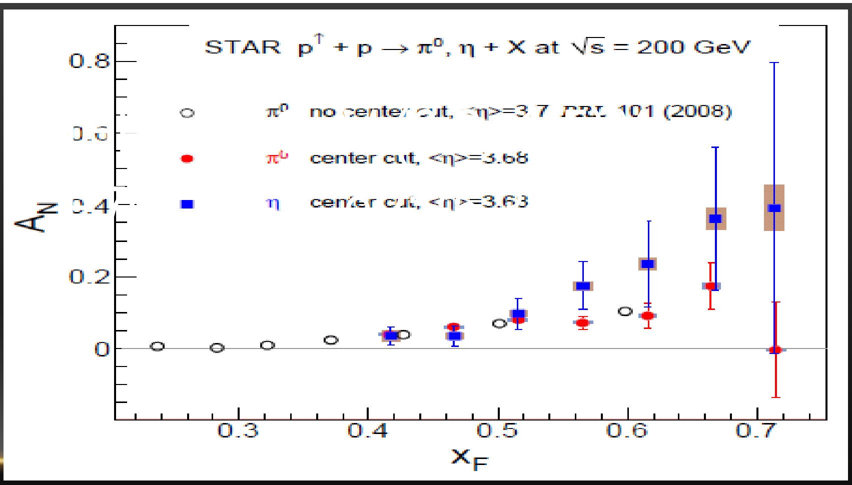


PROZA-M INCLUSIVE Π⁰ PRODUCTION



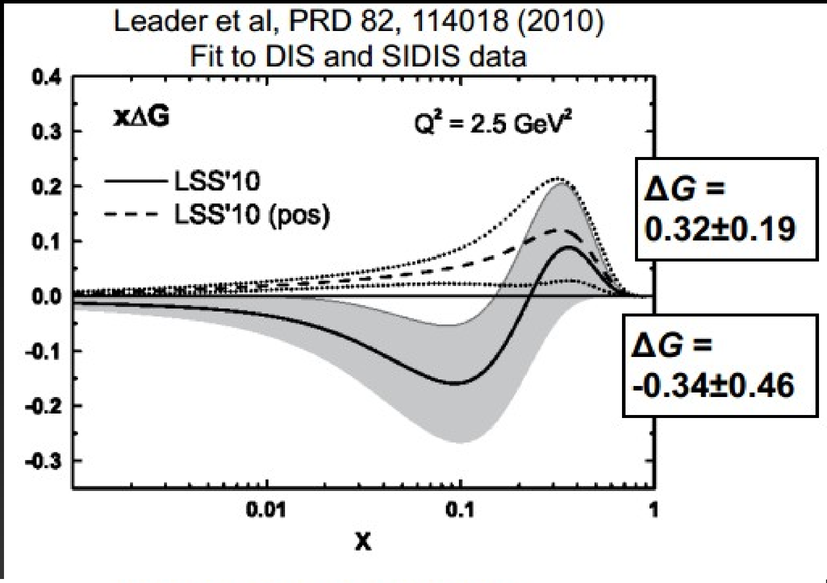


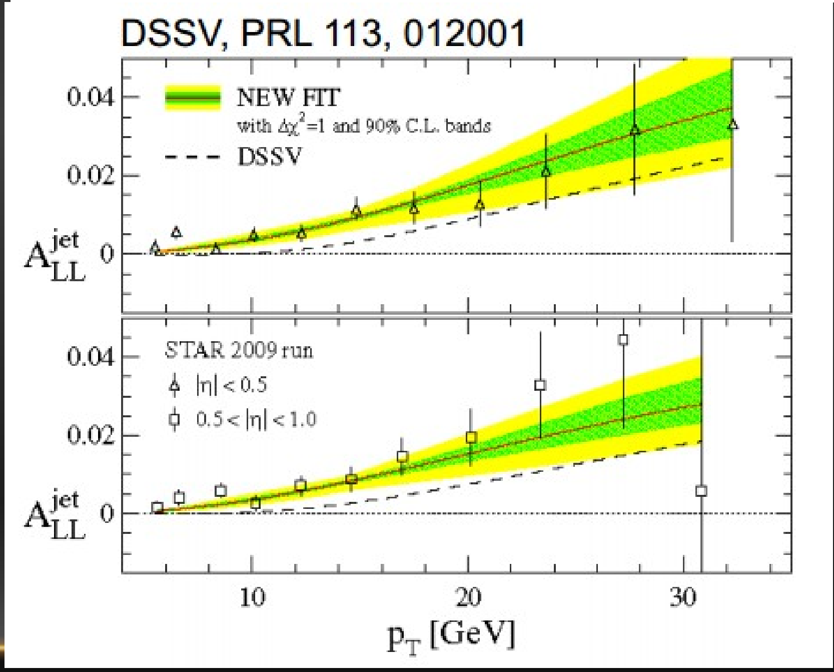




PROTON SPIN STRUCTURE

- EMC, HERMES, CMS discovered, that spin of the proton is not the sum of quark spins (only 30%)
- Gluon contribution seems also small (between 0 and 20%)
- Orbital moment contribution is required
- Nevertheless RHIC announced first observation of non-zero ΔG/G. evidence for positive gluon polarization:
- 0.23 ± 0.07 for 0.05 < x < 0.5





DETECTOR DESCRIPTION

- Tracking system ΔP/P=0.4% at 10 GeV/c:
  - Spectrometer magnet (1.5 Tm Field), full aperture 300x600 mrad,
  - 2 GEM stations,
  - 5 thin-wall drift tube chamber stations (20 plates, 60 sub-planes)
- Particle identification
  - Cherenkov 1: pions above 3 GeV/c, kaons above 11 GeV/c,
  - Cherenkov 2: pions above 6 GeV/c and kaons above 23 GeV/c,
  - Hodoscopes as TOF (p/K-separation up to 2.5 GeV, K/pi up to 1.5 GeV)

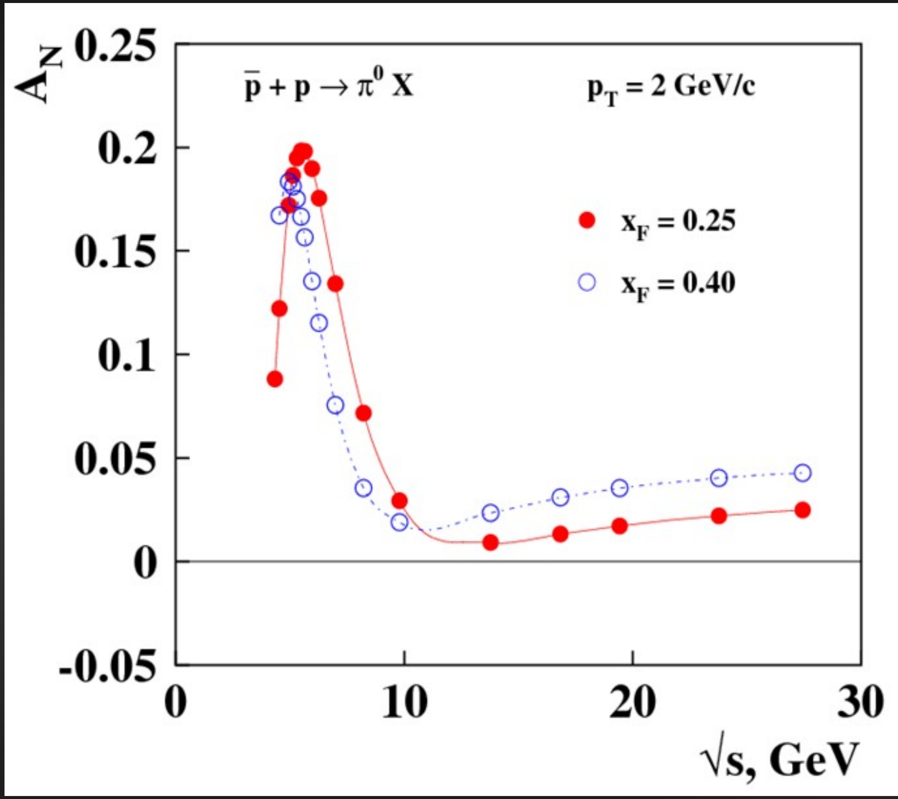
DETECTOR 2

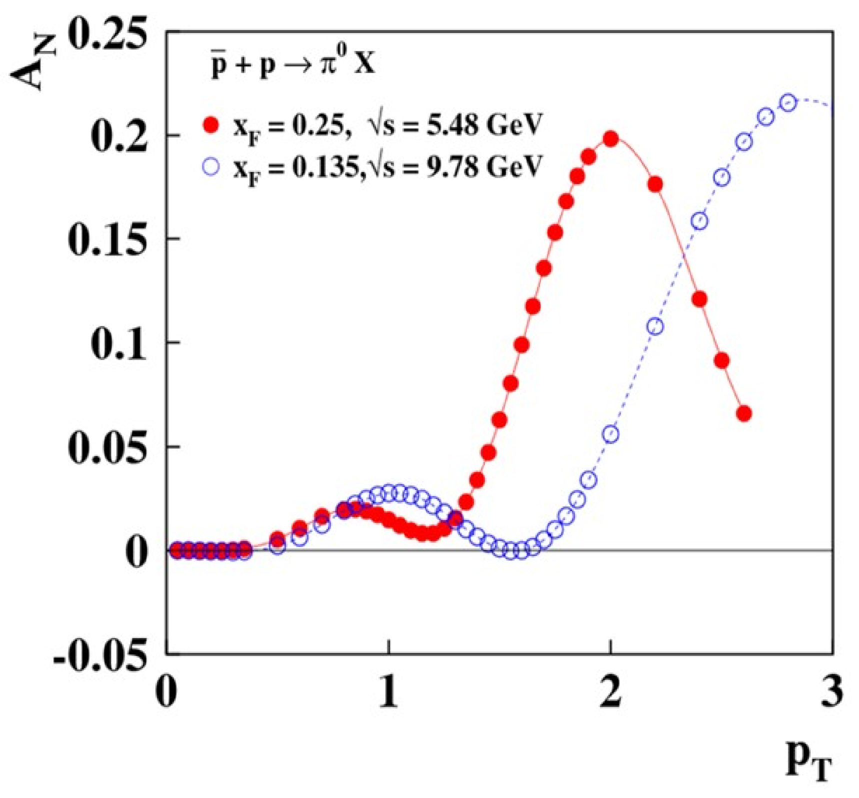
- Calorimetry:
  - Fine-segmented lead-scintillator electromagnetic calorimeter (shashlyk-type): $\sigma(E)/E=1.3\oplus 2.8/\mathrm{sqrt}(E)$, 5.5x5.5 cm cell size (Full transverse size 2x3 m)
  - Compensated lead-scintillator hadron-calorimeter (sandwich, 7 int. length, about 50/sqrt(E))
- Muon detector
- Beam detectors: Tagging system in the intermediate focus, 2 Scintillation fiber hodoscopes (fiber width 0.44 cm), GEM station, Threshold Cherenkov counters
- Polarimetry
  - Tagging at intermediate focus, beam momentum measurements and absolute polarimeter

STAGE 1 PHYSICS

- Systematic study of spin effects for the particles from light (u,d,s) quarks:
  - Single-spin asymmetry in unpolarized beam fragmentation region
    - Exclusive meson production with the registration both neutral and charged particle. Expected asymmetry 30-40% and oscillation.
    - Asymmetry in the reaction $\pi^- p_\uparrow \rightarrow a_0(980)n \rightarrow \eta(550)\pi^0 n$ will be measured for the first timeI
    - Inclusive reactions
    - Hyperon(?) and vector-meson study
- Single spin effects with polarized proton and antiproton beams

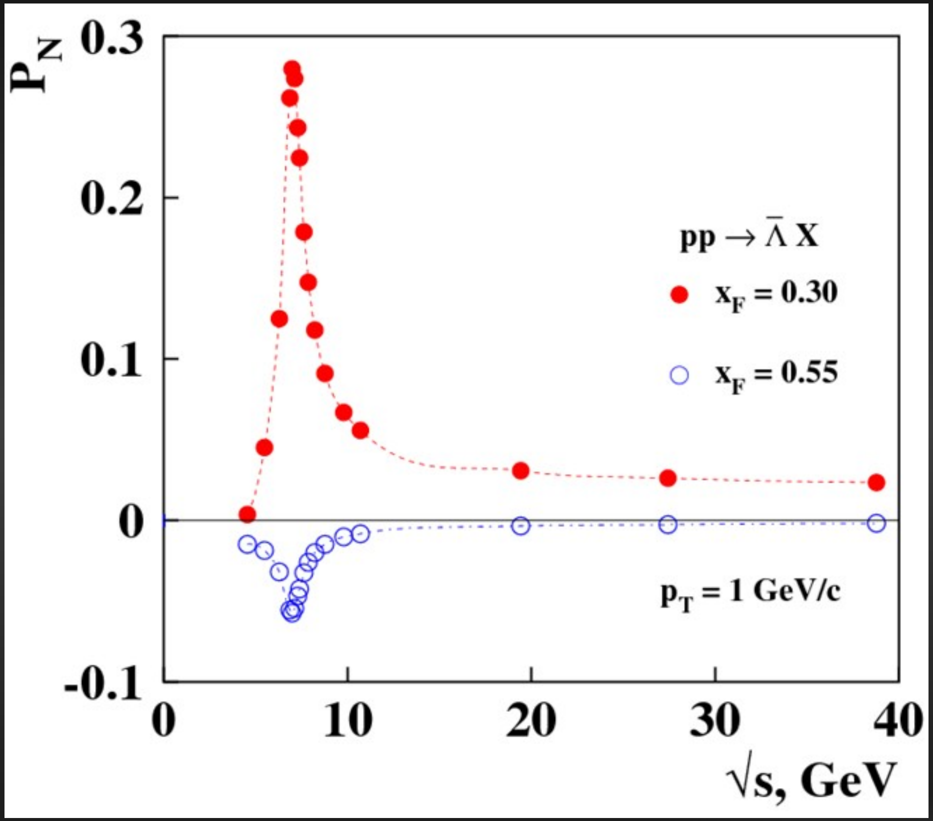
EXPECTATIONS (PREDICTIONS) OF EFFECTIVE COLOR FIELD MODEL

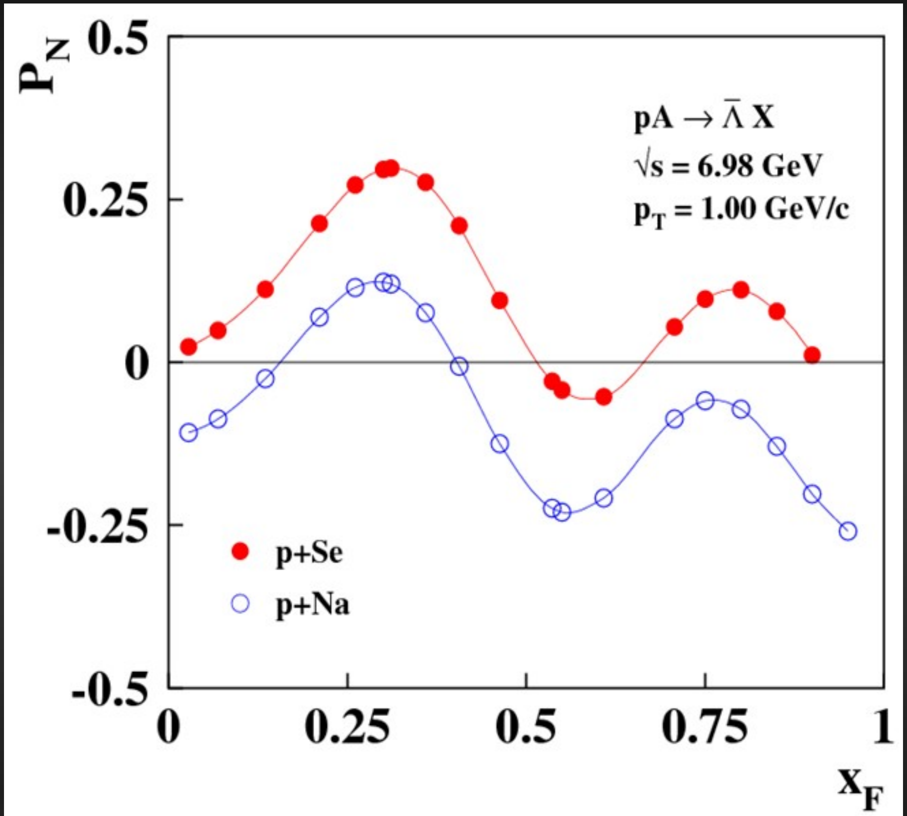




There are predictions for many different reactions versus kinematical variables and target atomic weight

PREDICTIONS FOR $\bar{\Lambda}$ POLARIZATION IN PP, PA-COLLISIONS





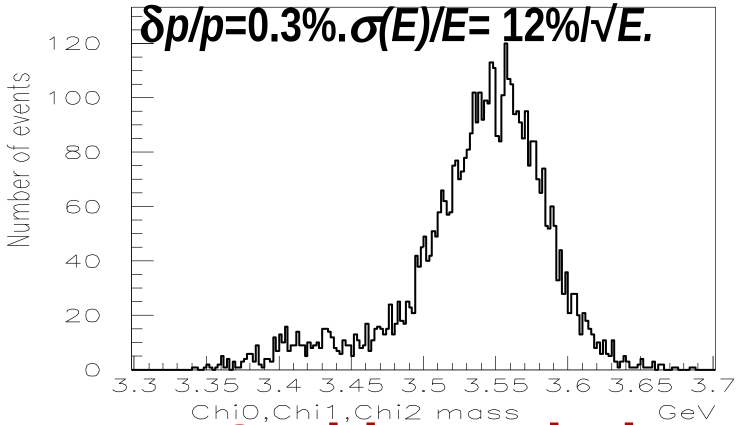
SPASCHARM EXPECTED STATISTICS USING 34 GEV K^--BEAM (ONE MONTH DATA TAKING – IN PARALLEL WITH π^--BEAM)

№	particle	N_{EV}	B/S	№	particle	N_{EV}	B/S
1	π^+	$6.7\cdot10^8$		13	$\rho^-(770)\to\pi^-\pi^0$	$7.5\cdot10^7$	3.8
2	π^-	$8.9\cdot10^8$		14	$\eta'\to\gamma\gamma$	$7.3\cdot10^5$	6.0
3	K^+	$8.9\cdot10^7$		15	$\varphi(1020)\to K^+K^-$	$1.0\cdot10^7$	0.05
4	K^-	$4.0\cdot10^8$		16	$K^{0*}(892)\to K^+\pi^-$	$1.3\cdot10^7$	1.2
5	p	$6.8\cdot10^7$		17	$\tilde{K}^{0*}(892)\to K^-\pi^+$	$6.6\cdot10^7$	0.8
6	p·	$3.7\cdot10^7$		18	$K^{-*}(892)\to K^-\pi^0$	$3.4\cdot10^7$	2.2
7	n	$6.2\cdot10^7$		19	$\Xi^-\to\Lambda\pi^-$	$2.5\cdot10^6$	0.02
8	$\pi^0\to\gamma\gamma$	$4.2\cdot10^8$	0.13	20	$\Lambda\to p\,\pi^-$	$1.8\cdot10^6$	0.02
9	$\eta\to\gamma\gamma$	$2.5\cdot10^7$	0.8	21	$\tilde{\Lambda}\to\tilde{p}\,\pi^+$	$2.9\cdot10^5$	0.08
10	$K^0_S\to\pi^+\pi^-$	$2.2\cdot10^7$	0.25	22	$\Lambda\to n\,\pi^0$	$4.0\cdot10^5$	0.6
11	$\rho^0(770)\to\pi^+\pi^-$	$6.8\cdot10^7$	2.7	23	$\Sigma^-\to n\,\pi^-$	$3.1\cdot10^6$	5.0
12	$K^0_S\to\pi^0\pi^0$	$4.2\cdot10^6$	1.1				

CHARMONIUM MONTE-CARLO SIMULATION

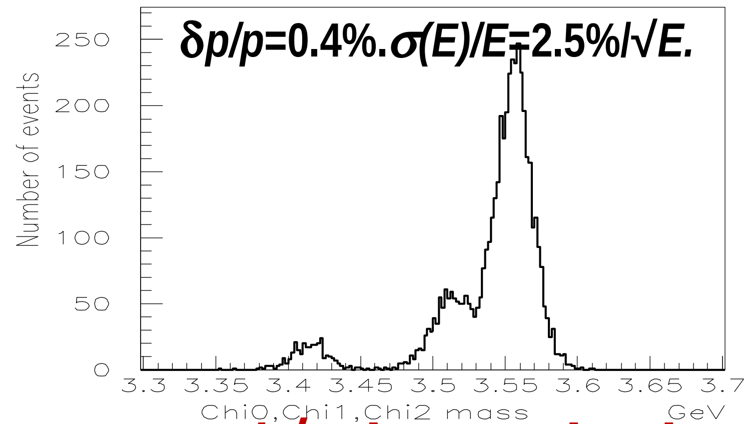
Without 1C fit.

$\delta p/p$=0.3%.$\sigma(E)/E$= 12%/√E.



Without 1C fit.

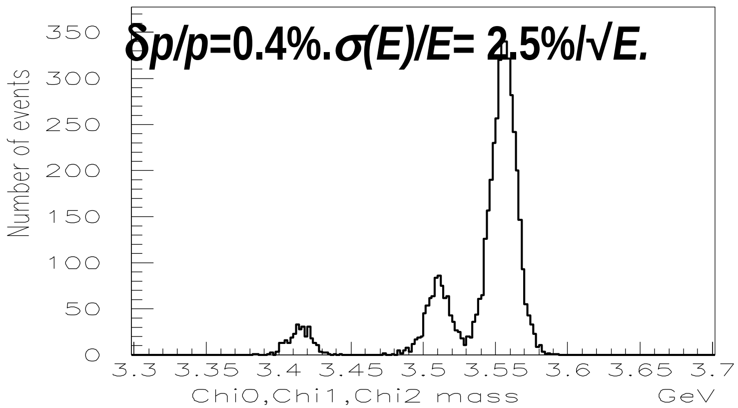
$\delta p/p$=0.4%.$\sigma(E)/E$=2.5%/√E.



EMC with resolution close to 2.5%/√E is required

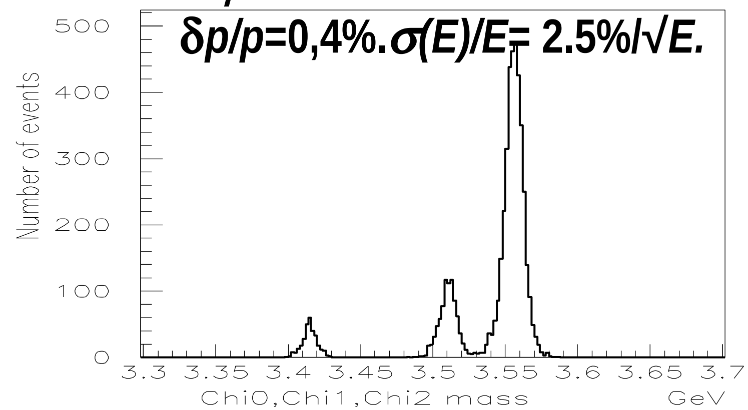
With 1C fit

$\delta p/p$=0.4%.$\sigma(E)/E$= 2.5%/√E.



J/ψ momentum from PHYHIA.

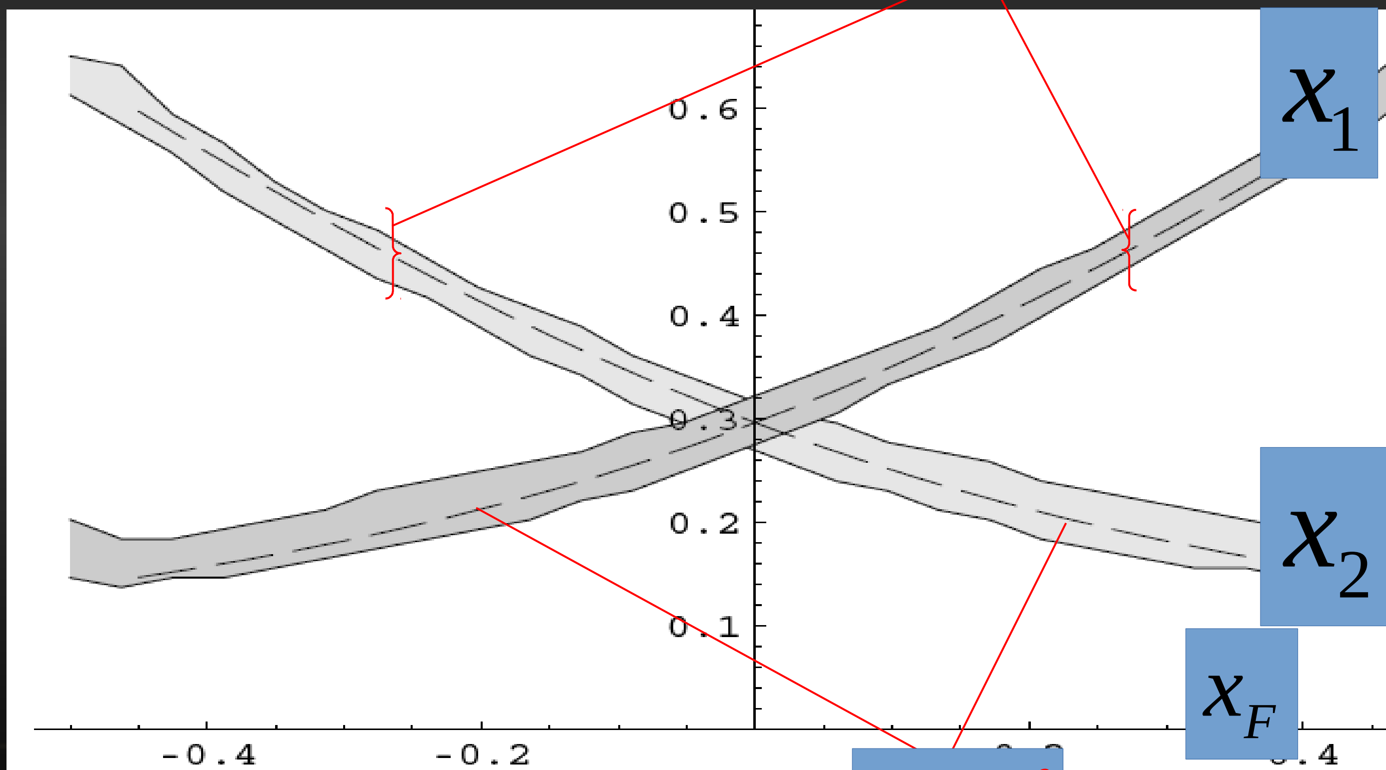
$\delta p/p$=0,4%.$\sigma(E)/E$= 2.5%/√E.



REGISTERED X □(X X)

$$x_F = \frac{\hat{s}+M^2}{2\hat{s}}\left(x_1 - x_2\right) + \frac{\hat{s}-M^2}{2\hat{s}}\cos\hat{\theta}_{13}\left(x_1 + x_2\right) \Rightarrow x_{1,2} \approx \frac{1}{2}\left(\sqrt{x_F^2 + \frac{4\hat{s}}{s}} \pm x_F\right)$$

$$\frac{d^2\sigma}{dx_F dx_{1,2}} > \frac{1}{2}\left(\frac{d^2\sigma}{dx_F dx_{1,2}}\right)_{\max}$$

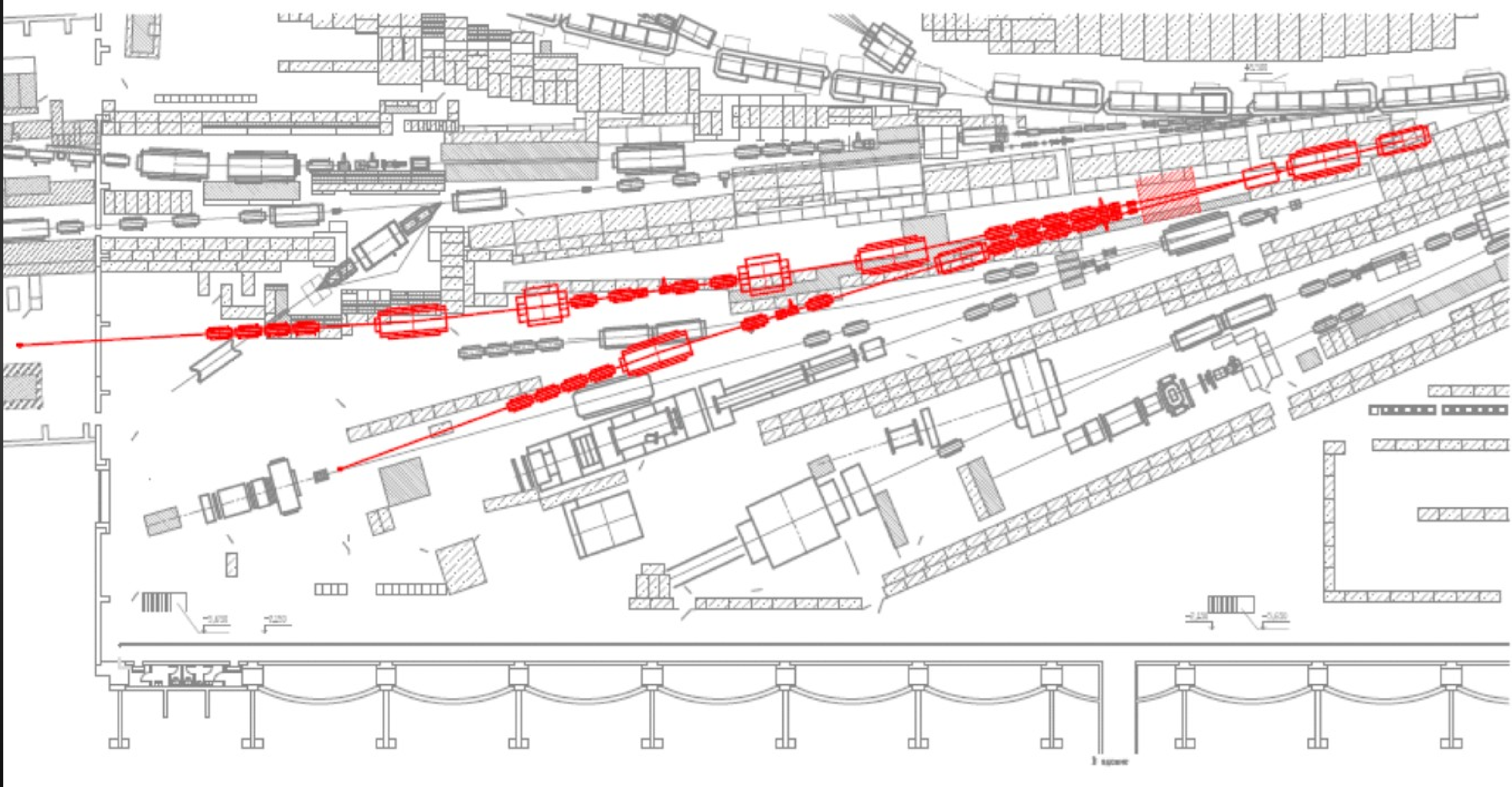


$\hat{s} = 1.3M^2$

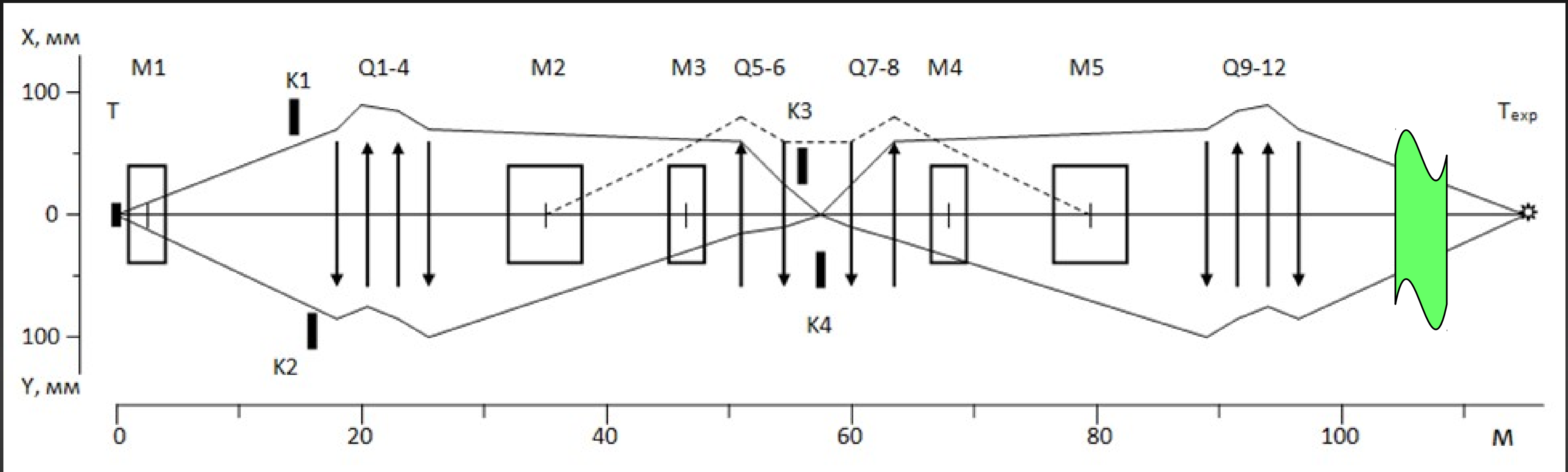
SPASCHARM POLARIZED BEAM OPTION

- Beam will be delivered to external target (up to $2 \cdot 10^{13}$ p/cyc.) to create secondary beams in the beam-line 24
  - 24A – polarized beam channel (polarized protons and antiprotons, unpolarized hadron and electron beams)
  - 24B – unpolarized hadron and electron beams

SPASCHARM BEAM-LINE 24A



OPTICAL SCHEME CHANNEL 24A



Main optic scheme for polarized beam p≤40 GeV/c from hyperon-decay. *Q – quads, M – dipoles K – collimators, T , T_{exp} – targets (channel and experiment), green – spin flipper (Novosibirsk - Shatunov)*

POLARIZED PROTON BEAM 40 GEV/C

Momentum collimator position	Min	Max
Momentum spread $\Delta p/p$, %	±4.5 (σ=2.1)	11.0 (σ=5.3)
Beam size, $\sigma_X \times \sigma_Y$, mm	13 × 11	17 × 14
Beam divergence $\sigma_X \times \sigma_Y$, mrad	1.6 × 2.0	1.5 × 1.9
Full intensity for 10^{13} protons in the target at 60 GeV	4.9×10^7	1.3×10^8

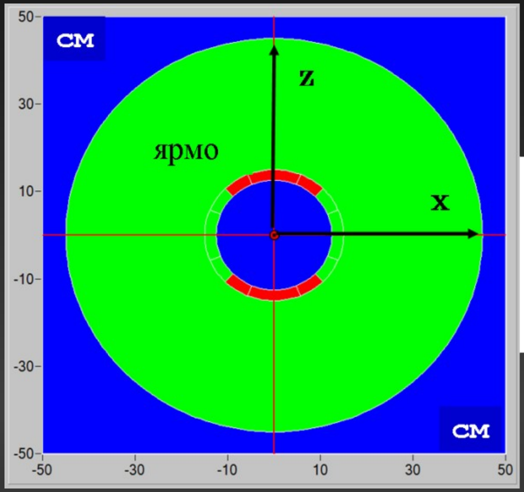
Polarized proton beam energy may vary between 12 and 50 GeV

POLARIZED ANTIPROTON BEAM (14 GEV/C)

Momentum collimator position	Min	Max
Momentum interval Δp/p, %	±5.5 (σ=2.3)	12.0 (σ=5.6)
Beam size, $\sigma_X \times \sigma_Y$, mm	18 × 19	20 × 19
Beam div $\sigma_{x'} \times \sigma_{y'}$ nce $\sigma_X \times \sigma_Y$, mrad	1.6 × 1.9	1.5 × 2.0
Full intensity for 10^{13} protons	1.4×10^5	3.9×10^5

Anti-proton P, GeV/c	Full anti-proton beam intensity for 10^{13} p/cyc. @ ext. target
10	1.9×10^5
14	3.9×10^5
20	3.4×10^5
30	9.3×10^4
40	1.6×10^4

SPIN FLIPPER (SHATUNOV TALK)



2 Helical magnets:

B_{max} = 47 kGs; λ= 2.5 m

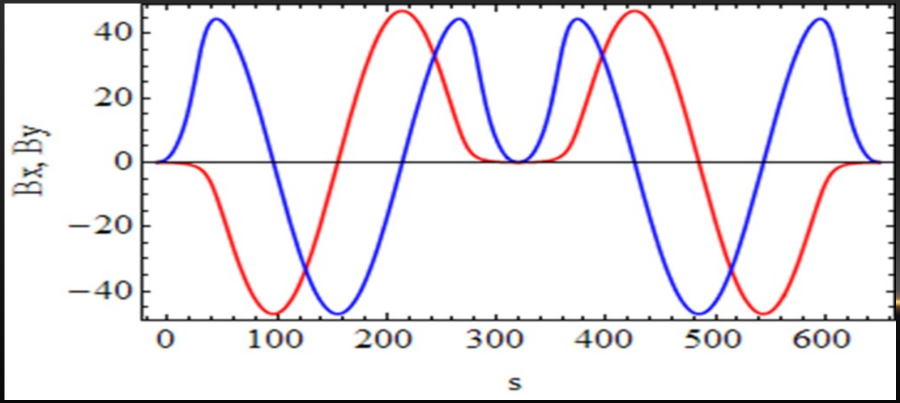
Correctors:*L*=30 cm; B= 23 kGs;

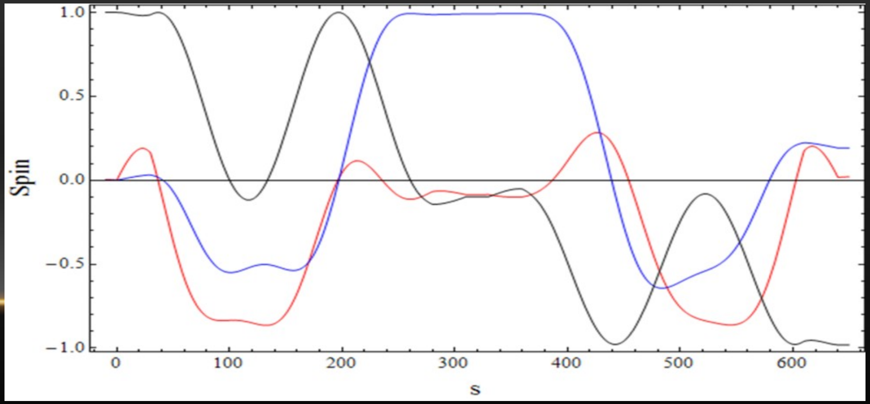
tilt = ± 0.1 rad;

Total length 6.5 m

Flipper optics: practically is equal to empty straight 6.5 m;

Spin transparency ≈ 97%





SPASCHARM SCHEDULE

- Polarized beam at the beam-line 24
  - 2014 – Design
  - 2015-2016 – Construction
  - 2017 - Commissioning
- SPASCHARM
  - 2014 – Setup commissioning
  - 2014-2016 – SSA measurements with the new Dubna polarized target at the beam-line 14
  - 2016(2017) – Transition to the beam-line 24
  - 2017 – Start of the SSA measurements with the polarized beam

THE SPASCHARM TEAM

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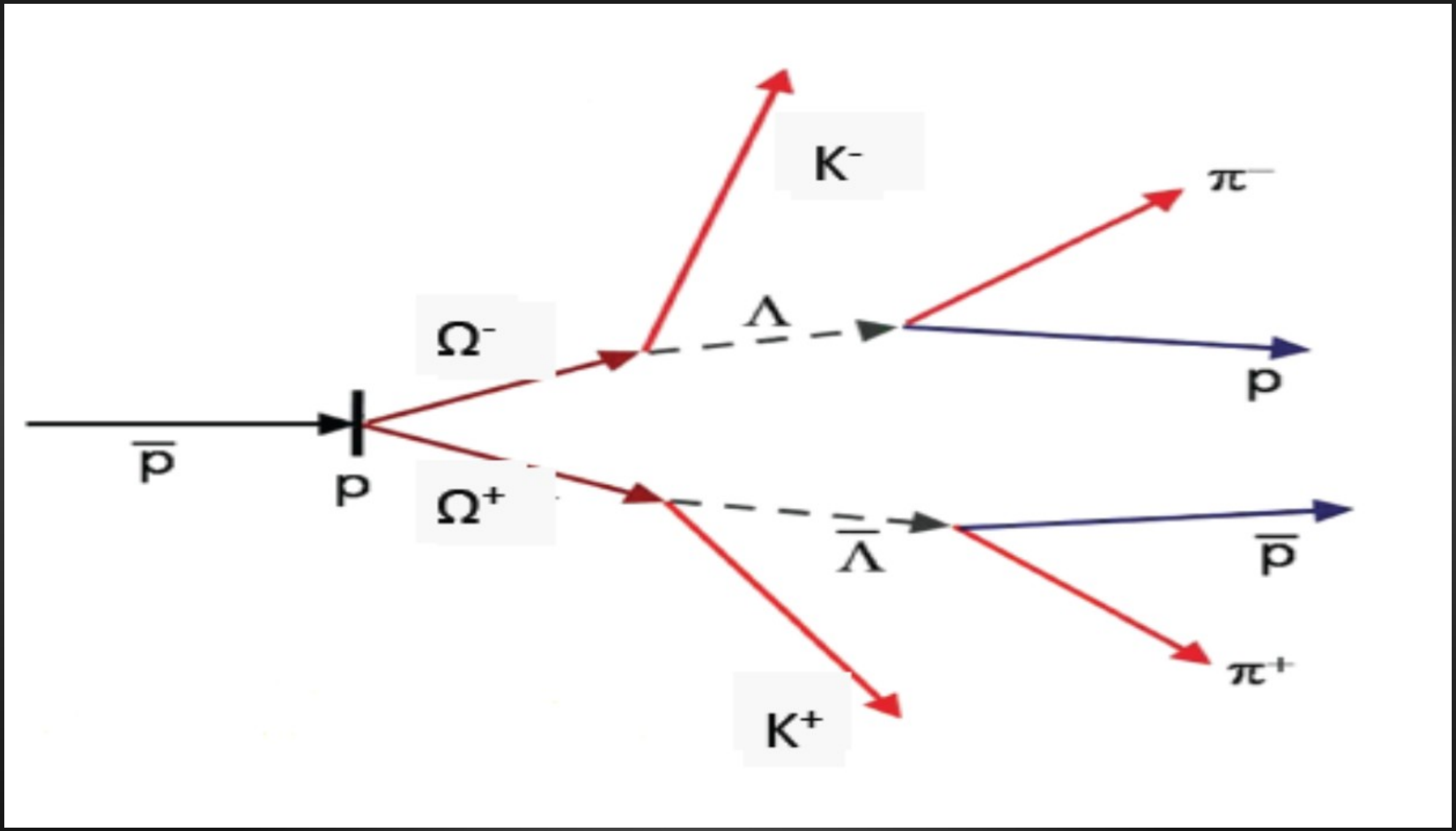
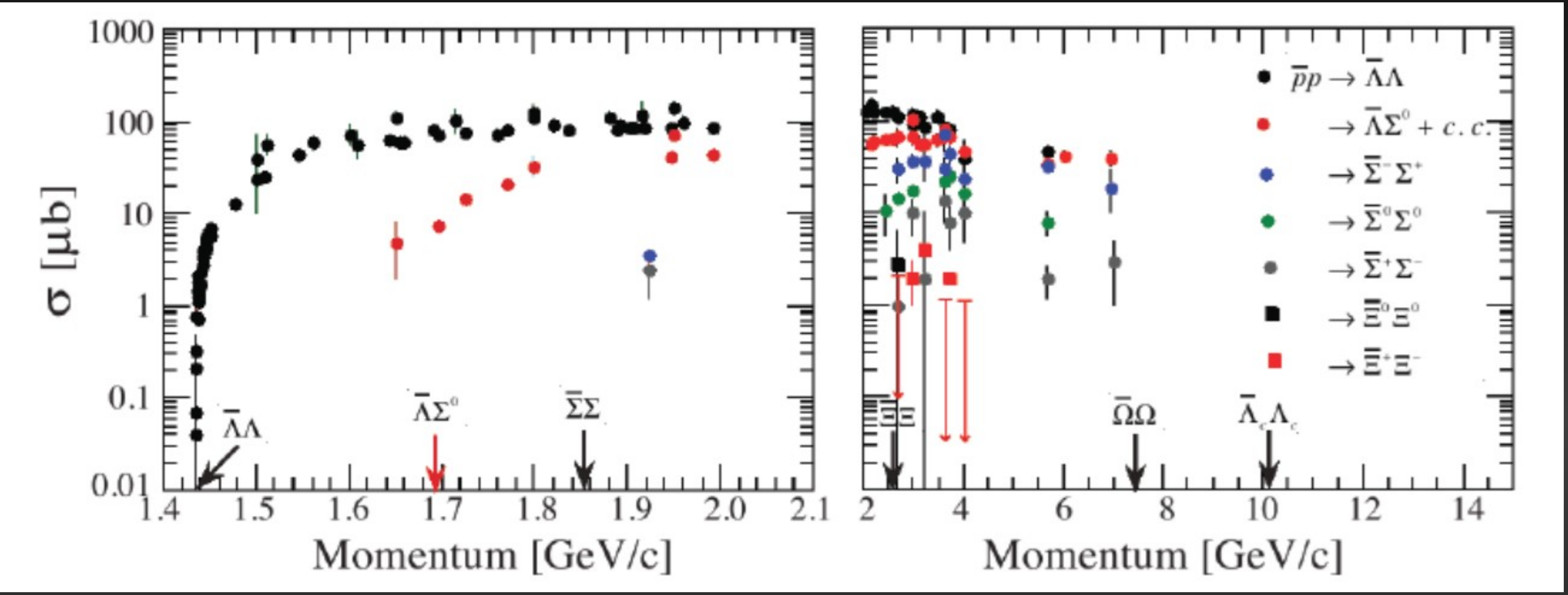
- V. Chetvertkova, M.Chertvertkov (MSU, Moscow)
- I.Koop, A.Otboyev, E.Perevedentsev, P.Shatunov, Yu.Shatunov (BINP, Novosibirsk)

FAIR FACILITY

HYPERON-ANTI-HYPERON PRODUCTION



PAIR HYPERON PRODUCTION

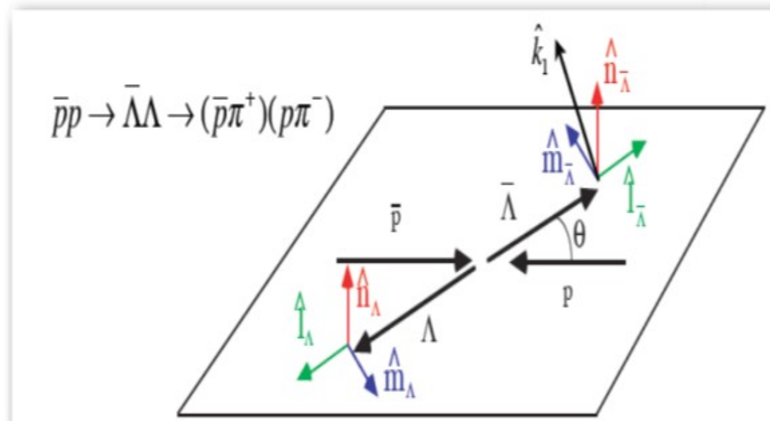


Almost full symmetry for the particles an anti-particles gives unique possibility to measure CP effects minimizing systematics

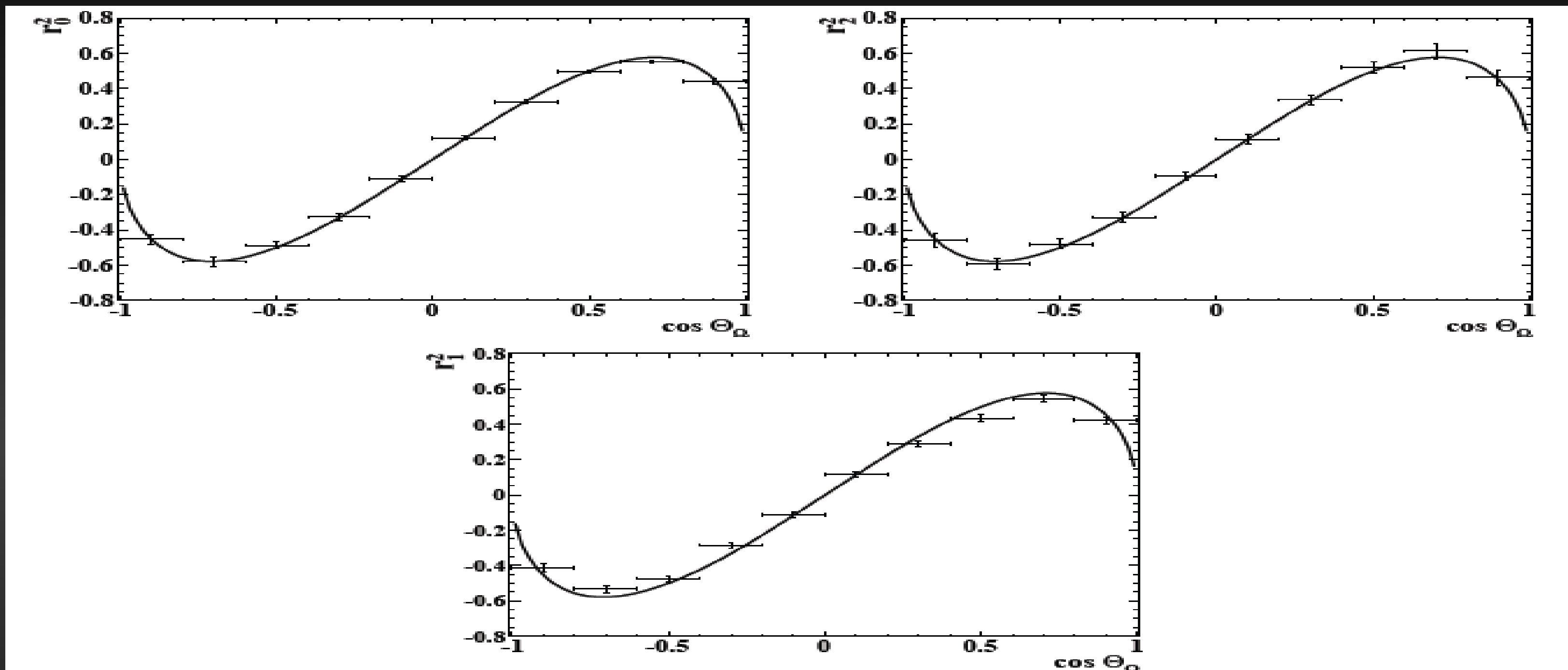
BARYON SPECTROSCOPY (ERIK THOMÉ PHD)

- The weak hyperon decay gives access to polarisation and spin correlations.
  - Access to spin degrees of freedom in $\bar{s}s$ and $\bar{c}c$ quark-pair creation.
  - Many observables
    - PWA of the data to extract relevant quantum numbers (resonances)
    - high discriminating power between models (hadron or quark-gluon based)
  - High x-sec for $\bar{p}p \to \bar{\Lambda}\Lambda$: CP-violation tests
  - Powerful reactions for Baryon Spectroscopy

Hyperon	Quarks	Mass [Mev/c^2]	cτ [cm]	α	Decay channel	B.R. [%]
Λ	uds	1116	8.0	+0.64	$p\pi^-$	64
Σ^+	uus	1189	2.4	-0.98	$p\pi^0$	52
Σ^0	uds	1193	$2.2\text{x}10^{-9}$	-	$\Lambda\gamma$	100
Σ^-	dds	1197	2.4	-0.07	$n\pi^-$	100
Ξ^0	uss	1315	8.7	-0.41	$\Lambda\pi^0$	99
Ξ^-	dss	1321	4.9	-0.46	$\Lambda\pi^-$	100
Ω^-	sss	1672	2.5	-0.03	ΛK^-	68
Λ_c^+	udc	2285	$6.0\text{x}10^{-3}$	-.98(19)	$\Lambda\pi^+$	1



POLARIZATION STUDY IN $\bar{p}p \to \bar{\Omega}^{+}\Omega^{-}$



Expressions for extracting polarisation parameters derived using the spin density formalism. 7 non-zero parameters:
3 parameters from the $\Omega \to \Lambda K$ decay
4 parameters from combined $\Omega \to \Lambda K$ and $\Lambda \to p\pi$ angular distributions.

The total Ω polarisation can be obtained by summing the square of these 7 parameters.